PATENT

Attorney Docket No. 502827.000010

NONPROVISIONAL APPLICATION FOR UNITED STATES LETTERS PATENT

for

HIGH FREQUENCY PULSE WIDTH MODULATION

by

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EV339945089US	July 16, 2003	AWeiss
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HIGH FREQUENCY PULSE WIDTH MODULATION

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[0001] Any references cited hereafter are incorporated by reference to the maximum extent allowable by law. To the extent a reference may not be fully incorporated herein, it is incorporated by reference for background purposes and indicative of the knowledge of one of ordinary skill in the art.

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

[0002] The present invention relates generally to the field of noise reduction.

DESCRIPTION OF RELATED ART

[0003] Excess and unwanted noise has become a problem throughout much of society. Unwanted noise is often found to be distracting, thereby preventing people from giving their full concentration to tasks on which they attempt to keep their attention.

[0004] For example, a person attempting to give full attention to soft sounds such as the soft sounds associated with a quiet scene in a movie would find himself hindered in that regard if the movie could not be played without an associated and distracting unwanted noise accompanying the playing of the movie. As another example, a person attempting to concentrate on tasks in a work environment may find efforts significantly hindered by unwanted noise, whatever its source.

[0005] A particularly widespread source of such unwanted noise is noise produced by electrical devices. Many attempts have been made to reduce the noise levels produced by electrical devices. Many such attempts have met with at least some degree of success.

[0006] The heat dissipation issues associated with computing devices has lead the vast majority of such devices to include some sort of cooling device. It is often the case that such cooling devices create unwanted noise.

[0007] Of course, if the only cooling device implemented by a particular electrical device is a fixed heat sink, no noise would be created. By contrast, cooling fans such as those found in personal computers and notebook computers, as well as other computing devices, are notorious for creating a significant amount of unwanted noise. However the effectiveness of cooling fans in dissipating heat, as well as their relative inexpensiveness, has caused them to be widely used despite the unwanted noise they produce.

[0008] One approach to reducing the noise produced by cooling fans has been to specially shape rotors of the cooling fan in order to reduce unwanted noise produced as the rotor generates air flow. Another approach has been to adopt specially shaped stationary frame blades to reduce the amount of unwanted noise created by air flow passing around such frame blades. A third approach to reducing the unwanted noise produced by cooling fans has been to operate such cooling fans submaximally. By reducing the speed of the fan, the amount of noise created by rotor creation of air flow and by air flow around frame blades is reduced. Despite these improvements, a substantial amount of unwanted noise is still created by cooling fans.

[0009] Similarly, the use of cooling blowers to dissipate heat from computing devices is associated with generation of a significant amount of unwanted noise. One approach to reduction of such unwanted noise has been to adopt specially shaped air paths. Such a specially air path results in generation of less noise associated with such air flow. Likewise, as with cooling fans, another approach has been to operate cooling blowers at submaximal blower speed in order to reduce the amount of unwanted noise produced by such blowers. However a substantial amount of unwanted noise is still produced by cooling blowers.

[0010] Another class of electrical devices which generate unwanted noise is digital video recorders. As discussed above, use of a digital video recorder to play a movie having a quiet scene with soft noises which the viewer desires to hear can be significantly

hindered by unwanted noise produced by the digital video recorder itself.

[0011] Medical devices would also benefit from reduction of the amount of unwanted noise they produce. For example, a medical device used during surgery that produces a significant amount of associated unwanted noise would naturally tend to hinder the concentration of the surgeon.

[0012] While many attempts to reduce unwanted noise produced by electrical devices have been successful, a further reduction of unwanted noise would provide concrete and substantial benefit.

BRIEF SUMMARY OF THE INVENTION

[0013] The present invention achieves a further reduction in the amount of unwanted noise produced by electrical devices by providing an electrical device having pulse width modulation controls for providing a plurality of settings for operation of the device. The electrical device includes a system for selectively controlling the frequency of the pulse width modulation to provide a desired output operational intensity in response to a known input signal. The system includes a high frequency pulse width modulation signal module adapted to provide frequencies above the audible range of anticipated users of the device. By providing frequencies above the audible range of anticipated users, the unwanted noise produced by the electrical device is reduced or eliminated. The high frequency pulse width modulation signal module includes a signal converter. The signal converter receives the known input signal and converts that signal into a high frequency pulse width modulation output signal, which is then used to control the operational intensity of the device. The production of unwanted noise is reduced because the output signal has a frequency above the audible range of anticipated users of such electrical device.

[0014] More preferably, the signal converter includes a high frequency signal generator and a comparator module. The high frequency signal generator produces a triangle signal having a frequency above the audible range of anticipated users of the electrical device.

The comparator module receives the triangle signal and performs a comparison operation with the triangle signal and the known input signal as input parameters. The comparator module then outputs the high frequency pulse width modulation output signal.

[0015] Still more preferably the present invention comprises a personal computing device including a housing, first memory space, second memory space, processor, and cooling device. The first memory space, second memory space and processor are all oriented within the interior of the housing. Whether the first memory space and second memory space are implemented on a single memory device, two memory devices or more than two memory devices is immaterial for purposes of the present invention. The first memory space is suitable for storing program instructions. The second memory space is suitable for storing data. The processor is operatively connected to both memory spaces. The processor is adapted to receive and execute the program instruction of the first memory space. The processor is further adapted to receive data from and send data to the second memory space.

[0016] The cooling device is configured to cool the interior of the personal computing device. Operatively, the cooling device has pulse width modulation controls for providing a plurality of settings for operation.

[0017] The cooling device includes a system for selectively controlling the frequency of the pulse width modulation to provide a desired output cooling intensity in response to a known input signal. The system includes a high frequency pulse width modulation signal module adapted to provide frequencies above the audible range of anticipated users of such a personal computing device. The signal module includes a signal converter which receives the known input signal and converts that signal to a high frequency pulse width modulation output signal suitable to operate the cooling device at the desired output cooling intensity. Unwanted production of noise is reduced or eliminated because the output signal has a frequency above the audible range for anticipated users of the personal computing device.

[0018] These and other advantages of the present invention will be more fully appreciated by the following detailed description of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] The following drawings form part of the present specification and are included to further demonstrate certain aspects of the present invention. The figures are not necessarily drawn to scale. The invention may be better understood by reference to one or more of these drawings in combination with the detailed description of specific embodiments presented herein.

[0020] **FIG. 1** is a schematic depiction of an electrical device of the prior art having its operational intensity directly controlled by a DC input signal.

[0021] **FIG. 2** is a schematic drawing of an electrical device of the prior art. The operational intensity of the electrical device is controlled by a DC input signal which is converted to a low frequency pulse width modulation signal.

[0022] **FIG. 3** is a schematic drawing of an electrical device according to the present invention which includes a signal converter for receiving a known input signal and converting that signal to a high frequency pulse width modulation output signal for controlling the operational intensity of the electrical device.

[0023] **FIG. 4** is a schematic drawing of another electrical device according to the present invention. The figure shows a more preferred implementation of the signal converter.

[0024] **FIG. 5** is a schematic drawing showing an even more preferred embodiment of an electrical device according to the present invention. In this embodiment, the known input signal is a DC input signal.

[0025] **FIG. 6** is a schematic drawing that shows the most preferred embodiment of the present invention. The electrical device is shown in the most preferred embodiment to include an operational intensity control circuit, a high frequency signal generator, and a comparator module.

[0026] **FIG. 7** shows a schematic drawing of an alternative embodiment of the present invention. A high frequency signal converter is included to scale a high frequency

triangle signal.

[0027] **FIG. 8** is a schematic drawing of another alternative embodiment of the present invention including a DC-to-DC converter that scales a DC input signal.

[0028] **FIG. 9** is a schematic drawing of a further alternative embodiment that includes a low frequency pulse width modulation-to-high frequency pulse width modulation converter.

[0029] **FIG. 10** is a schematic drawing of yet another embodiment of the present invention. This embodiment includes a low frequency pulse width modulation-to-DC converter and a DC-to-high frequency pulse width modulation converter.

[0030] **FIG. 11** is a schematic drawing of a still further embodiment of the present invention. This embodiment includes an RC circuit for performing low frequency pulse width modulation-to-DC conversion.

[0031] **FIG. 12** is a schematic drawing of a further alternative embodiment including a thermistor input and a thermistor signal-to-high frequency pulse width modulation converter.

[0032] **FIG. 13** is a schematic drawing of an additional alternative embodiment. This embodiment includes a thermistor as well as a high frequency signal generator and a comparator module.

[0033] **FIG. 14** is a schematic drawing of a personal computing device according to the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0034] It will be understood by those skilled in the art that the present invention can be implemented in a number of different ways, within the scope of the claims appended hereto. A presently preferred embodiment of the invention will now be described below.

[0035] An electrical device **14** of the prior art is shown in **FIG. 1**. The operational intensity of electrical device **14** is controlled directly by DC input signal **12**. Control is achieved by varying the DC input signal level. This approach to controlling operational

intensity creates several problems. A significant amount of heat is generated which must be dissipated. Power inefficiencies occur and electronic and microelectronic components tend to be harmed by variation of voltage levels. As adoption of electronic and microelectronic components has become extremely widespread, the increased electronic and microelectronic failure rate associated with using DC input signals to directly control the operational intensity of electrical devices has become a problem.

[0036] **FIG. 2** shows an approach to solving several of the problems present in the prior art electrical device shown in **FIG. 1**. A DC-to-low frequency pulse width modulation converter **16** converts DC input signal **15** into low frequency pulse width modulation signal **17** which then controls the operational intensity of electrical device **18**.

[0037] By definition, pulse width modulation signals are either at 100% or at 0%. Therefore, variation of voltage which has been shown to be harmful to electronic components is avoided. Consider the case where DC input signal **15** can range from 2 volts to 3 volts. If DC input signal **15** is 2.5 volts, the low frequency pulse width modulation signal **17** corresponding to DC input signal **15** will have a 50% duty cycle. That is, the pulse width modulation signal **17** will, over time, will have a value of 1 about 50% of the time and a value of 0 about 50% of the time. Electrical device **18** is controlled to maintain a steady operational intensity by rapid switching of the pulse width modulation signal **17** between 0 and 1. However, if the electrical switching occurs at a speed within the frequency range of human hearing, such switching will produce audible noise. The range of human hearing is usually considered to be about 20 Hz to about 20 kHz. However, women typically have sensitivity to higher frequencies than men. In addition, the maximum audible frequency changes with age, declining at about 1 Hz per day. The upper limit of human hearing for a 15-year old will typically be 20 kHz. Therefore, a 40-year old would typically be expected to have a hearing range of about 11 kHz. A 70-year old would typically be expected to have an upper frequency hearing limit of 2 to 4 kHz.

[0038] Moreover, the maximum frequency which a person can hear can be damaged by exposure to high sound levels over extended periods.

[0039] It is an important realization that the frequency of a pulse width modulation signal is independent of its duty cycle. Simply stated, the frequency of a pulse width modulation signal is the rate at which the signal switches between 0 and 1. The present invention provides a solution to reducing unwanted noise produced by electrical devices by using high frequency pulse width modulation.

[0040] Turning to **FIG. 3**, a preferred embodiment A1 of the present invention is depicted. The operational intensity of electrical device **24** is ultimately controlled by known input signal **21**. System **20** of the preferred embodiment A1 includes a signal converter **22** that converts known input signal **21** into high frequency pulse width modulation output signal **23**. The output signal **23** directly controls the operational intensity of electrical device **24**. The electrical switching noise that would normally be produced by the pulse width modulation output signal **23** is rendered inaudible by selecting its frequency above the upper limit of anticipated users of the device.

[0041] **FIG. 4** shows a similar and more preferred embodiment A2. Signal converter **122** receives known input signal **21** and converts the signal **21** into high frequency pulse width modulation output signal **123** in order to control the operational intensity of electrical device **24** without the production of audible noise associated with the electrical switching of the pulse width modulation of output signal **123**. Signal converter **122** includes a high frequency signal generator **25**. Generator **25** produces a high frequency triangle signal **26** which is sent as an input to comparator module **27**. Comparator module **27** also takes as a second input known input signal **21**. Module **27** performs a comparison operation on signals **21** and **26** in order to produce output signal **123**.

[0042] **FIGS. 5** and **6** are schematic drawings of embodiments B1 and B2, which are even more preferred. Embodiment B1 includes an electrical device **48** having its operational intensity controlled directly by high frequency pulse width modulation output signal **47**. Signal converter **46** produces signal **47** by converting DC input signal **45**. Output signal **47** has a frequency set above the range of audible hearing of anticipated users of the device.

[0043] Turning to **FIG. 6**, the most preferred embodiment B2 of the present invention

is depicted schematically. Embodiment B2 includes a signal converter **146** and an electrical device **148**. Signal converter **146** includes a high frequency signal generator **51**, which produces a high frequency triangle signal **52** for input into a comparator module **53**. Module **53** performs a comparison operation on DC input signal **45** and input signal **52** in order to produce a high frequency pulse width modulation output signal **147**.

[0044] The electrical switching inherently required in pulse width modulation output signal **147** is set at a frequency above the range of audible hearing of anticipated users of the device in order to eliminate the unwanted noise that would be produced by a lower frequency pulse width modulation output signal. Electrical device **148** is shown to include an operational intensity control circuit **49** and the remaining portion of electrical device **50**. The control circuit **49** receives the output signal **147** and controls the operational intensity of electrical device **148** accordingly.

[0045] Two alternative embodiments of the present invention are shown in FIGS. 7 and 8 as embodiment C1 and embodiment C2. Alternative embodiment C1 includes a signal converter **32** and an electrical device **39**. Signal converter **32** is similar to converter **146**, difference being that the high frequency triangle signal **34** which is produced by high frequency signal generator **33** is scaled by high frequency signal converter **35** to produce a scaled high frequency triangle signal **36**. The triangle signal **34** is converted by scaling into signal **36** in order to facilitate the comparison operation within module **37** occurring and taking DC input signal **31** as a second input, sending high frequency pulse width modulation output signal **38** to operational intensity control circuit **40** for selectively controlling the operational intensity of the remaining portion **41** of electrical device **39**.

[0046] Turning to FIG. 8, signal converter **132** is similar to signal converter **146** (shown in FIG. 6). A difference between the converters **132** and **146** is that converter **132** includes a DC-to-DC converter **135** which converts DC input signal **131** into a scaled DC input signal **136**. High frequency triangle Signal **134** is produced by high frequency signal generator **133** in order to facilitate the comparison operation performed by comparator module **37**, which takes signal **134** as its other argument. The output of module **37** is high frequency output signal **138**. Signal **138** is input into operational

intensity control circuit **40** which accordingly controls the remaining portion of electrical device **41**. Control circuit **40** and remaining portion **41** make up electrical device **39**.

[0047] **FIGS. 9, 10** and **11** are schematic drawing of further alternative embodiments D1, D2 and D3. **FIG. 9** shows an electrical device **64** having its operational intensity controlled ultimately by a low frequency pulse width modulation input signal **61**. Signal **61** is converted to a high frequency pulse width modulation output signal **63** by a low frequency pulse width modulation-to-high frequency pulse width modulation converter **62**. **FIG. 10** includes converter **162** which converts low frequency pulse width modulation input signal **61** into high frequency pulse width modulation output signal **163**. Converter **162** includes a low frequency pulse width modulation-to-DC converter **65**, which receives as an input signal **61** and produces as its output DC signal **66**. Converter **162** also includes a DC-to-high frequency pulse width modulation converter **67** which takes as its input signal **66** and produces as its output signal **163**, for controlling the operational intensity of device **64**.

[0048] Embodiment D3 shown in **FIG. 11** is similar to embodiments D1 and D2. Low frequency pulse width modulation input signal **61** ultimately controls the operational intensity of electrical device **64**. Converter **262** includes a low frequency pulse width modulation-to-DC converter comprising an RC circuit **165**. Circuit **165** converts signal **61** into DC input signal **166**. Converter **262** also includes converter **167** which takes as its input DC input signal **166** and produces as its output high frequency pulse width modulation output signal **263**. Converter **167** includes a high frequency signal generator **68** and a comparator module **70**. Generator **68** produces a high frequency triangle signal **69** as its output. Module **70** takes signal **69** as its input, as well as signal **166**, and performs a comparison operation thereon, producing high frequency pulse width modulation output signal **263**. Electrical device **64** takes output signal **263** as its input which controls its operational intensity.

[0049] While several alternatives to the preferred embodiments have been discussed, including various examples of known input signals, a great many types of known input signals are encompassed within the spirit and scope of the invention as appreciated by

those skilled in the art. For example, **FIGS. 12** and **13** are schematic drawings which show other alternative embodiments E1 and E2. Embodiment E1 includes a signal converter that comprises a thermistor signal-to-high frequency pulse width modulation converter **75**. Converter **75** takes thermistor input signal **74** as its input and produces corresponding high frequency pulse width modulation output signal **76** as its output. Electrical device **77** takes signal **76** as its input which thereby controls the operational intensity of device **77**.

[0050] Embodiment E2 includes thermistor **73** signal converter **175** and electrical device **77**. Converter **175** includes a high frequency signal generator **78** and a comparator module **80**. Generator **78** produces a high frequency triangle signal **79** which is taken as one input of module **80**. Thermistor **73** produces a DC input signal **174** which is taken as another input of module **80**. Module **80** performs a comparison operation on signal **174** and signal **79**, producing corresponding high frequency pulse width modulation output signal **176**. Device **77** takes signal **176** as its input which thereby controls the operational intensity of device **77**.

[0051] **FIG. 14** is a schematic illustration of a personal computing device according to the present invention. The personal computing device includes housing **83** which defines an interior **90** of the personal computing device. The personal computing device also includes a first memory space **84**, a second memory space **85**, a processor **86** and a cooling device **89**. Memory spaces **84** and **85** and processor **86** are oriented within interior **90**. It is immaterial for purposes of the present invention whether memory spaces **84** and **85** are implemented on a single memory device, on two memory devices, or on more than two memory devices. First memory space **84** is adapted to store program instructions. Second memory space **85** is adapted to store data. Processor **86** is operatively connected to first memory space **84** by operative connection **87**. Processor **86** is also operatively connected to second memory space **85** by operative connection **88**. Processor **86** is adapted to read program instructions from memory space **84** and to execute such instructions. Processor **86** is also adapted to receive data from memory space **85** and to send data to memory space **85**. Cooling device **89** is configured to cool

the interior **90** of housing **83**. The operational intensity of cooling device **89** is controlled by a high frequency pulse width modulation signal. The frequency of the signal is selectively set sufficiently high as to be above the upper audible limit of the frequency range of hearing of anticipated users of the personal computing device **82**. Cooling device **82** is shown as being framed within the structure of on wall of housing **83**. However, as in the other variations and modifications that will be appreciated by those of skill in the art and encompassed within the spirit and scope of the claims, cooling devices **82** may be oriented in any relationship to the housing **83** suitable to allow cooling device to cool interior **90**.

[0052] The phrase "electrical device" is used herein to indicate any device having an operational intensity that may be controlled by a pulse width modulation signal.

[0053] Any element in a claim that does not explicitly state "means for" performing a specified function, or "step for" performing a specific function, is not to be interpreted as a "means" or "step" clause as specified in 35 U.S.C. § 112, ¶ 6. In particular, the use of "step of" in the claims herein is not intended to invoke the provision of 35 U.S.C. § 112, ¶ 6.

[0054] It should be apparent from the foregoing that an invention having significant advantages has been provided. While the invention is shown in only a few of its forms, it will be understood by those skilled in the art that it is not limited to only those embodiments but is susceptible to various changes and modifications without departing from the spirit and scope of the invention. For example, the electrical device could include additional controls by which the upper limit of the audible range for anticipated users could be selectively set in order to flexibly accommodate users having different audible range upper limits. Additionally, multiple electrical devices could be controlled by branching a high frequency pulse width modulation output signal to provide as an input into each of the electrical devices. These and other changes and modifications will be apparent to those skilled in the art in view of the above disclosure and are within the spirit and scope of the invention.

[0055] By way of further example of variations falling within the spirit and scope of

the invention, use of the word "connect" or any of its derivatives in this specification and in the appended claims implies not only a direct, immediate connection between two recited parts, but also embraces the various arrangements wherein the parts are operatively connected, although other elements may be physically located or eliminated between the connected parts. Similarly, the word "a" does not preclude the presence of a plurality of elements accomplishing the same function. Additionally, use of the words "send," "receive," or any of their derivatives in this specification and in the appended claims implies not only a direct, immediate transmission between two elements, but also embraces the various arrangements wherein the transmission operatively occurs, although other elements may intervene in the transmission, or the transmission between two elements may otherwise occur indirectly.